Successful Experimental Validation of an Integrated Burst Mode Receiver Designed for 10G-GPON Systems in a Packet-OADM Metro Network

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Abstract: A burst mode receiver designed for 10G-GPON systems was tested in a packet-optical add/drop multiplexer metro network. Fast power dynamic range and OSNR tolerance recordings demonstrate that this receiver is compliant with metro network requirements.
OCIS codes: (060.4259) Networks, packet-switched, (040.1345) Avalanche photodiodes (APDs);

1. Introduction

The current deployment of xPON systems worldwide requiring low cost burst mode transmitters and receivers is creating new opportunities for upper network segments, in particular the metro network. An integrated DC-coupled burst mode receiver (BMRX) [1] has been designed and realized for 10G-GPON systems in the framework of the European projects MARISE and EuroFOS. In parallel a packet-optical add/drop multiplexer (P-OADM) metro network concept, exploiting an optical packet technology, was studied and implemented within the framework of the European project ALPHA to explore low cost and low power consuming networks. This new technology was investigated in an extended end-to-end network model covering home networks to metro networks. Both access networks and metro networks are cost sensitive since a non negligible part of the traffic is managed locally. So any device designed and optimized for the access network and compatible with the network requirements of the metro area pointing relevant potential cost reductions, is of prime interest.

Thus in this paper, we analyze the potential of the BMRX designed for 10G-GPON systems, in a P-OADM metro network demonstrator as described in [2]. The 10Gbit/s BMRX was characterized in a network configuration to analyze its potential in terms of OSNR tolerance, RX sensitivity penalty and fast packet power dynamic range supported.

2. The structure of the 10Gbit/s Burst Mode Receiver

The 10Gbit/s DC-coupled BMRX contains a newly developed APD-based burst-mode trans-impedance amplifier (BM-TIA) and a burst-mode limiting-amplifier (BM-LA) for 10G-GPON systems, as shown in the Fig. 1a [1]. The APD has an excess noise factor F=3.3 at M=10 and a gain-bandwidth product of 150-160GHz. In the BM-TIA three trans-impedance gain settings are employed to extend the RX dynamic range. With a fast gain control (FGC) and gain-locking function, it is able to switch its trans-impedance according to the received burst power within several nanoseconds. After the gain switching process, the TIA trans-impedance gain is finally locked in order to avoid bit error rate (BER) degradation due to gain switching inside the payload interval. The BM-TIA also performs a coarse threshold compensation (CTC) process to minimize the output DC offset.

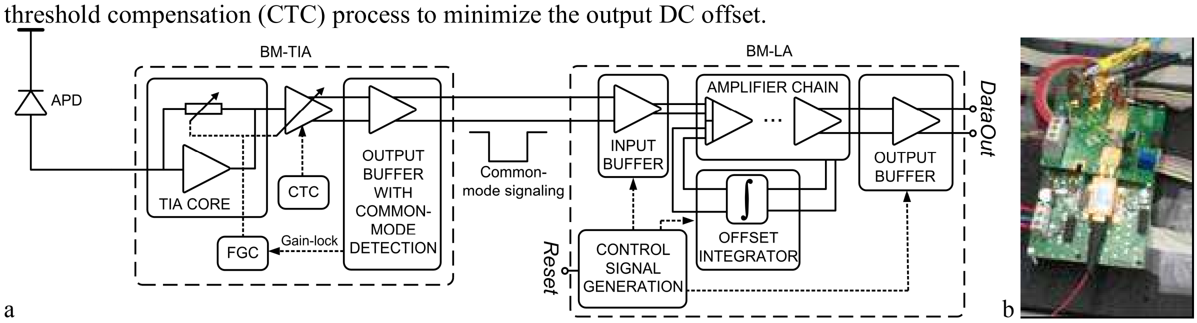


Figure 1: a: Building blocks of the BMRX, b: photo of the APD-TIA module and BM-LA test boards

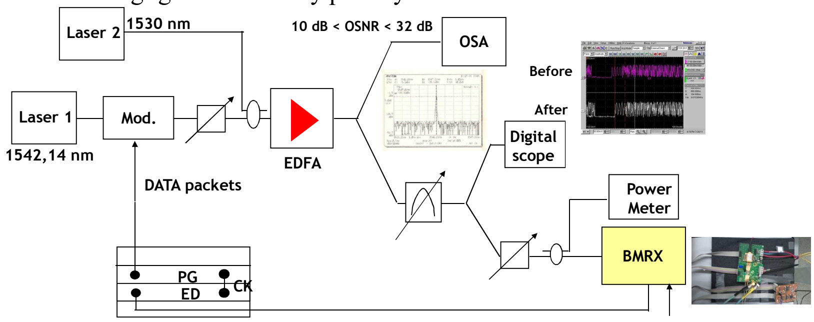
The subsequent 10Gbit/s feedback type BM-LA has two operation modes: a fast decision threshold level detection mode and a slow threshold level tracking mode. When a new burst arrives, the threshold detection circuit first performs a fast offset compensation and an amplitude recovery. Once the correct threshold is established, the BM-LA switches to the slow tracking mode, which is crucial to provide a higher tolerance to consecutive identical digits (CIDs). The BM-LA needs a burst-reset signal in this experiment, which is externally provided by the system. At the end of the burst, the BM-LA resets the threshold to the default state and waits for the arrival of a next burst. The output signal level of the BM-LA is current mode logic (CML).

3. Experiments of- BMRX used in Packet-OADM metro networks

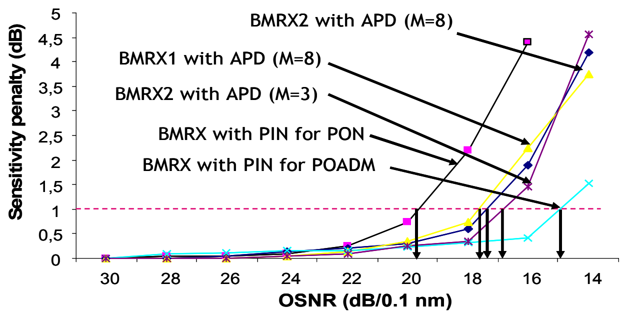
We will focus here our analysis on a P-OADM technology proposed for a new generation of metro networks studied in the ALPHA project. The data protocol called Optical Timeslot is using an optical packet including a guard band and a preamble. The major difference with a GPON system is that the signal can suffer from an OSNR degradation due to a large number of EDFAs and SOA gates in cascade.

In this experiment, we have then evaluated the impact of an optical noise on the BMRX sensitivity. Figure 2(a) shows the test bed used. Laser 2 had a fix output power to maintain the gain of the EDFA at a constant value. A main channel, at 1542.15 nm is then injected in the same EDFA through a 3dB coupler, but optically attenuated. At the output of the EDFA an optical filter is used to select the main channel. In parallel and before the filter, the optical spectra analyzer (OSA) gives the OSNR values in a 0.1 nm bandwidth.

Figure 2(b) shows then the RX sensitivity penalty obtained with four BMRXs and at different values of the OSNR. Two 10Gbit/s BMRXs are PIN photodiode-based, one was optimized for a PON system and another was optimized for an amplified optical network. Two other 10Gbit/s BMRX are APD-based recently designed for 10G-GPONs, where the gain (M factor) of the APD was modified to show the impact of the avalanche effect. Figure 2 (c), gives OSNR values for the BMRXs when the sensitivity is impacted by a 1dB penalty. We observe that the two APD-based BMRXs designed for 10G-GPON systems are well positioned (between the two PIN-based BMRXs) and can tolerate 18 dB of OSNR with a negligible sensitivity penalty.



(a)



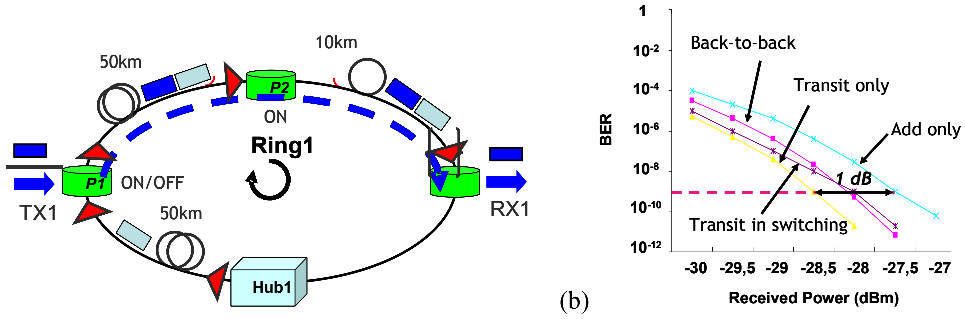
(b)

Burst Mode Receiver	OSNR for 1dB penalty
BMRX PIN, for PON	19,7 dB
BMRX APD M=8 n°1	17,7 dB
BMRX APD M=8 n°2	17,5 dB
BMRX APD M=3 n°2	16,8 dB
BMRX PIN, for POADM	14,8 dB

(c)

Figure 2(a): Testbed configuration, (b): RX sensitivity penalty versus OSNR, (c): OSNR for 1 dB sensitivity penalty with different BMRXs (10G-GPON APD-based BMRXs and PIN-based BMRXs)

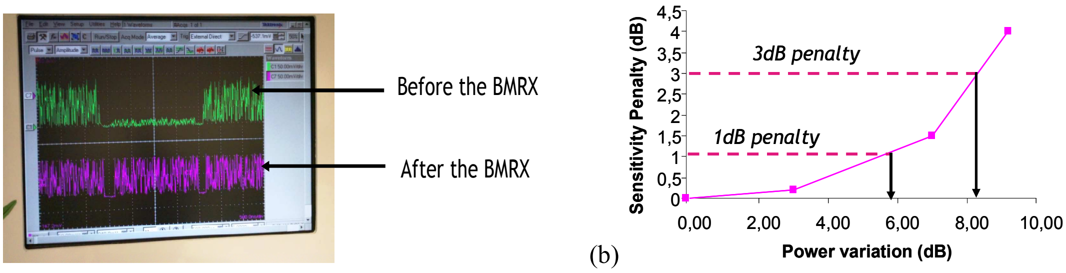
In a second step we have tested two versions of the APD_based BMRXs at the drop port of a P-OADM node. Figure 3(a) shows the testbed configuration. It is a ring metro network with one main node called Hub, generating 40 wavelengths all modulated at 10Gbit/s, and three sub-equipped P-OADM nodes. The distance between the main node and the last P-OADM node of the ring was 110 km. The DATA stream was composed with continuous optical packets (timeslots) of 2.048 µs, including a guard band of 200ns and a preamble of 76.8 ns. The third P-OADM was interconnected to a line card which was providing the reset signal to the BMRX. Figure 3(b) shows the BER characteristics at 1549.32 nm with one of the two BMRXs for the back-to-back configuration (transmitter only), for a transmission case crossing the network (for the transit and for the add) and for a packet switching regime interleaving packets generated by the Hub1 and inserted at P-OADM n°1 P1. We observe that a RX power sensitivity as low as -27.5 dBm is achieved in a packet switching regime with a sensitivity penalty well below 1dB.



(a) (b)

Figure 3(a): Optical packet ring metro network, (b): BER characteristics with the 10G-GPON BMRX

In a third step, we have tested the 10G-GPON BMRX in the context of fast packet power variations. Since we adopted a distributed scheme for the control of the power packet per packet using a detector of power and an SOA in gain control, the power variation at the output of a network is limited to a few dBs. Thus the requirements for the BMRX were to handle a maximum power variation between consecutive packets of 5 dB (cumulated value due to the non ideal equalization plus the power dispersion of the last network section). Since the metro network has been designed to cascade up to 10 nodes, with a minimum OSNR for the main channel close to 20dB/0.1 nm, a 5 dB power variation could create then a potential OSNR close to 15 dB. The curve of Figure 2(b) shows that in that case the sensitivity penalty becomes close to 3 dB when OSNR is 15dB. To measure the packet dynamic range, we have then plotted the curve of Figure 4(b), showing the power penalty evolution with the packet power variation. To have a representative curve, we adopted the worst case: the packet measured was lower in power than the other packet in order to identify the impact of a cumulated constraint (power + OSNR degradation). Figure 4(b) shows that a 3dB sensitivity penalty is obtained for packet power variations as large as 8 dB. This is because that during these experiments the OSNR of the bigger packet was close to 23 dB/0.1 nm. An analysis of the minimum preamble required has shown that 9.6 ns was enough for the packet at the sensitivity level, whereas 30 ns was required for the packet at the highest power level.



(a) (b)

Figure 4(a): Digital scope showing the trace before and after the 10G-GPON BMRX for a 10 dB power variation, (b): Sensitivity penalty at 10^{-9} with the 10G-GPON BMRX for different power variations

4. Conclusion

We have demonstrated for the first time that a BMRX designed for 10G-GPON systems is fully compatible with the network requirements of a P-OADM technology: large power dynamic ranges (10 dB) and tolerance versus optical noise were obtained as well as stable operation (10^{-15} obtained after 13 hours of BER measurements, with 18 dB of OSNR and for an input power of -19 dBm). The potentially low cost aspect is another great advantage of this device, to enable a technological solution in metro networks where cost issues are fundamental.

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5. References

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